Avocado oil extraction processes: method for cold-pressed high-quality edible oil production *versus* traditional production

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Abstract

Nowadays the avocado fruit (*Persea americana* Mill.) is widely regarded as an important fruit for its nutritional values, as it is rich in vital human nutrients. The avocado fruit is mainly sold fresh on the market, which however trades also a relevant quantity of second-grade fruits with a relatively high oil content. Traditionally, this oil is extracted from dried fruits by means of organic solvents, but a mechanical method is also used in general in locations where drying systems and/or solvent extraction units cannot be installed. These traditional processes yield a grade of oil that needs subsequent refining and is mainly used in the cosmetic industry. In the late 1990s, in New Zeland, a processing company with the collaboration of Alfa Laval began producing cold-pressed avocado oil (CPAO) to be sold as edible oil for salads and cooking. Over the last fifteen years, CPAO production has increased in many other countries and has led to an expansion of the market which is set to continue, given the growing interest in high-quality and healthy food. Avocado oil like olive oil is extracted from the fruit pulp and in particular shares many principles of the extraction process with extra-vergin olive oil. We conducted a review of traditional and modern extraction methods with particular focus on extraction processes and technology for CPAO production.

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Introduction

The avocado fruit originated in Southern Mexico where archaeological remains and other evidence indicate that its cultivation started in very ancient times, possibly some 6000 years ago. Avocados were grown at the time of the Conquest and spread from Northern Mexico southwards across Central America into North-Western Latin America, extending southwards in the Andean region down to Peru and eastwards into the Andean region of Venezuela (Popenoe, 1935). The commercial exploitation of avocado began in the early 1900's by Californians. Its production in the tropical areas of the world has grown steadily over the last decade and currently accounts for about three million and eight hundred thousand tons of fresh fruit. Most of the produce is grown for fresh consumption, which is also on the increase (FAO, 2014).

The avocado fruit (*Persea americana* Mill.) is widely regarded today as an important fruit for its nutritional values, as it is rich in vital nutrients for the human body. There has recently been an increasing demand in antioxidants, given their beneficial effects on human health. In this respect, avocados contain three of the most important ones, which are vitamins. Avocado fat consists predominantly of monounsaturated oleic acid, which has been found to reduce harmful low-density lipoprotein cholesterol, while maintaining beneficial high-density lipoprotein cholesterol, and to perform better than typical low-fat diets (Bergh, 1992; Fulgoni *et al.,* 2013). Although avocado is primarily consumed fresh, a substantial increase in the use of avocado-based products (*e.g.,* guacamole) and oil for cosmetics and culinary purposes also suggest further market growth (Bost *et al.,* 2013).

Avocado fruit and oil extraction

The avocado plants include three different horticultural varieties named after their presumed areas of origin: Guatemala, Mexico and West Indies. Each variety is marked by many different traits, some of which are of commercial relevance (Bergh and Ellstrand, 1986). Today, from the agronomical point of view, there are many varieties with a wide range of sizes, forms and compositions of the fruit. For instance, For instance, Table 1 reports the characteristics of different fruits from varieties harvested in Venezuela (Gómez López, 2002) and clearly shows an example of their variability in particular in terms of size, oil content and seed/pulp proportions. In general, the fruit is roughly pear-shaped and more or less elongated. Its weight may range from 60 g to 700 g. The relative amount of pulp varies from 60 to 75% according to the cultivar. The oil content may also vary widely. The kernel contains only about 1% of oil, whereas the skin accounts for less than 4% (Jacobsberg, 1988). Figure 1 shows the average composition of a Hass avocado from New Zealand. Requejo-Tapia (1999) in New Zealand described the Hass variety as being the most compatible with high-quality oil extraction due to its large amount of flesh with a high oil content. Depending on the location of the orchard, the oil content of these fruit flesh can range from 16-17% in September to 25-30% in April depending on the fruit ripening stage (Requejo-Tapia, 1999).

The market of fresh avocado is certainly the main one and also generates a remarkable quantity of second-grade produce which is discarded, despite its relatively high oil content. The avocado oil can be extracted in different ways. It is contained in a finely-dispersed emulsion in the cells of the fruit pulp. Hence, the extraction process requires rupturing not only the cell walls, but also the structure of the emulsion (Lewis *et al.,* 1978). Traditionally, this oil used to be obtained by mashing the pulp in water, then heating and skimming off the supernatant oil. Later, for cost reasons, most producers started to extract oil from dried fruits by means of solvents (Sadir, 1972; Human, 1987; Martinez Nieto *et al.,* 1988). Two main methods are in use to extract avocado oil for industrial production. According to the first method, fruits are dried and pressed at high temperature, subsequently oil is extracted by means of organic solvents. In the second method, oil is separated from fruits by centrifugal or pressing forces, then oil cells are submitted to mechanical and enzymatic distruction (Human, 1987; Werman and Neeman, 1987; Martinez Nieto *et al.,* 1988; Bizmana *et al.,* 1993). The second method was developed in order to cut energy costs and minimise the air pollution caused by organic solvents. Nevertheless, in both cases, the crude avocado oil still needs to be refined before final consumption and use in the cosmetic industry, where it is particularly appreciated for its high vitamin E content and emollient properties, although it is considered marginal as a food product (Eyres *et al.,* 2001). The first attempt to develop a method to produce cold-pressed oil intended to obtain high-quality edible oil was made back in the late 1990's by a New Zealand company in collaboration with Alfa Laval (Eyres *et al.,* 2001). In the follow paragraph we compare shortly the three main extraction methods: chemical extraction by solvent, traditional mechanical extraction and the most recent cold-pressed mechanial method for high-quality edible oil. In the description of the last one, we will focus in particular on Alfa Laval extraction plant, process parameters and oil quality. However this paper does not mention other variations of the main methods used in the past for avocado oil extraction (Human, 1987).

Chemical extraction by solvents

Organic solvent extraction is the most widespread. Warm air drying of the pulp followed by hexane solvent extraction yields 95% oil (oil extracted/oil content). The resulting oil is brownish with a high pigment content and needs to be refined for most applications. Refining consists of three steps: deacidification to remove free fatty acids which are less than 1% in good-quality fruits; bleaching to remove chlorophylls and their degradation products, pheophytins, as well as carotenoids; de-odourisation. When oil is sold crude, it is generally winterised at 5°C and drummed in lacquer-lined drums (Human, 1987; Martinez Nieto *et al.,* 1988).

Traditional mechanical extraction

The mechanical method has been used traditionally in locations where drying facilities and/or solvent extraction units cannot be insalled. However these processes have poor yields and frequently require the use of chemical aids.

Avocado oil extraction was generally obtained by peeling and destoning the fruit, mashing the pulp and eventually drying it, then heating the paste with hot water with chalk and/or NaCl, and spinning,

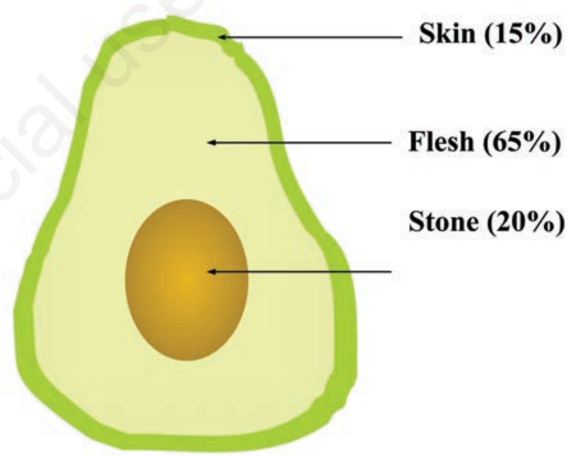

Figure 1. Average composition of a Hass avocado in New Zealand.

Table 1. Fruit characteristics of different varieties of avocado harvested in Venezuela in 1993. Fruit weight and pulp, seed and peel proportion and oil and moisture percentage (Gómez López, 2002).

Variety	Weight (g)	Pulp (%)	Seed (%)	Peel (%)	Oil (%)	Moisture (%)
Fuerte	192.86	70.90	17.04	12.06	11.23	82.85
Peruano	285.41	68.52	23.66	7.81	11.24	76.28
Lula	336.84	55.68	31.77	12.54	11.49	78.38
Red Collinson	322.87	67.23	19.14	13.63	11.74	82.19
Alcemio	317.62	61.94	26.95	11.11	11.82	76.52
Araira 1	350.63	71.61	17.85	10.54	13.08	79.08
Pope	405.09	76.88	11.80	11.33	13.36	75.83
Ettinger	267.91	76.49	17.37	6.14	14.72	78.54
Gripiña 5	215.72	60.26	27.51	12.24	15.15	76.43
Barker	364.33	73.84	18.10	8.06	17.55	74.24
Duke	108.84	67.49	24.52	7.98	18.18	74.33
Ryan	146.46	64.85	22.41	12.74	18.80	70.41

pressing or skimming off (by natural decantation) the oil (Figure 2) (Werman and Neeman, 1987; Bizmana *et al.,* 1993).

The centrifugation/pressing yield is 60-80% (oil extracted/oil content) depending on the fruit variety.

An extensive literature describes the mechanical method and compares different process conditions in relation to yield and oil quality. After peeling and de-stoning, the pulp is mashed with hot water. Werman and Neeman (1987) recommend a dilution ratio of 1/3 and a 30-min treatment at 75°C. Bizmana *et al.* (1993) found the best combination with a dilution ratio of 1/5 and a 5-min treatment at 98°C. Traditionally, the mechanical method gives low yields, which can however be increased by maintaining the pH between 4.0 and 5.5 by adding chalk ($CaCO_3$, $CaSO_4$) or salt (NaCl) to the paste before centrifugation. The presence of monovalent and divalent cations activates enzymes with pectinase activity, therefore at certain concentrations the cellulolytic and proteolytic activities are unaffected. The addition of salts favours the extraction from difficult pastes (Dominguez *et al.,* 1994). Bizimana *et al.* (1993) reported good results with an addition of 5% (w/w) $CaCO_3$ or $CaSO_4$. NaCl improves oil extraction only at a low concentration (<15%), but it causes a significant corrosion of the equipment (Werman and Neeman, 1987). Also when the traditional mechanical method is used, the resulting oil normally needs to be refined depending on the desired use. The refining system is the same described in the previous paragraph.

In a complete review about avocado oil (Jacobsberg, 1988), the author maintains that the mechanical extraction method compared with the chemical method and without chemical aids offers the best-quality oil, but it has an poor cost/benefit ratio. More recently has been demonstrated that oil extracted from pressed and microwave-dried avocado pulp presented the lowest acid and peroxide values and the highest oxidative stability in contrast with the oil from ethanol extraction. Combining microwave drying and pressing of avocado pulp seems to be able to led to a superior quality avocado oil (Santana *et al.,* 2015).

Cold-pressed extraction: complete process plant from Alfa Laval

In the late 1990's, a processing company in New Zealand began production of cold-pressed avocado oil (CPAO) to be sold as culinary oil for salads and cooking (Eyres *et al.,* 2001). This project was developed in collaboration with Alfa Laval, a leading food processor, which leveraged its significant experience and technological expertise in cold-pressing extra-virgin olive oil (EVOO) to develop a novel extraction method to obtain high-quality avocado edible oil. Like EVOO, CPAO is not refined and maintains the chemical, organoleptic and flavour profile of the fruit flesh. In the 2008/2009 season, the New Zealand processors produced more than 150,000 liters of CPAO with approximately 3% of the avocado crop grown for oil production (Wong *et al.,* 2010). Today CPAO is produced also in Chile, South Africa, Kenya, Israel, Samoa and other countries. Subsequently they built a complete processing plant to

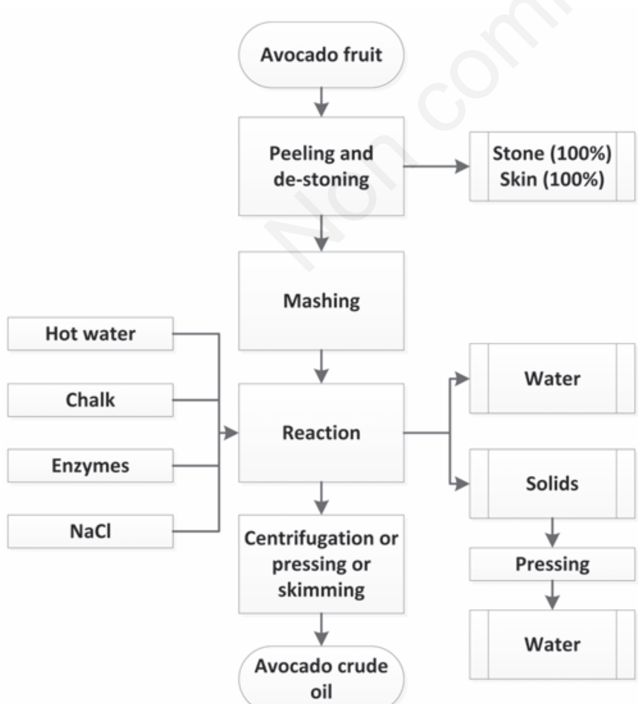

Figure 2. Flow-chart of the traditional mechanical extraction method for avocado oil production.

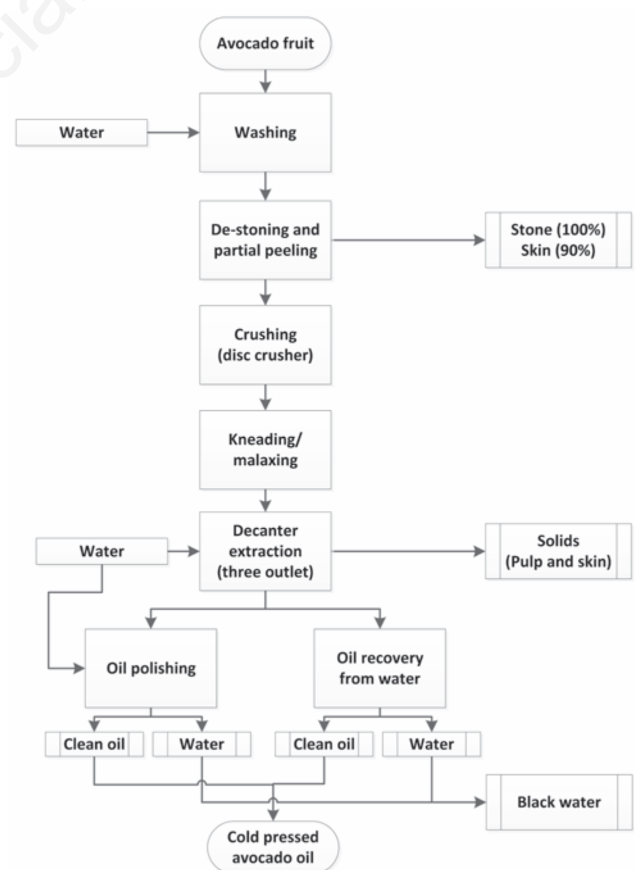

Figure 3. Flow-chart of the cold-pressing mechanical extraction method from Alfa Laval.

extract CPAO from the avocado fruit. The extraction process in use is showed in the flow chart described in Figure 3.

Fruit washing, destoning, deskinning and mash preparation

Whole fruits are washed in a two-stage washing system (Figure 4A). The first washing is performed by immersion in order to remove dust from the surface of the fruits. The soft water flow generated by a jet system gathers fruits by a plastic bucket elevator, which has two functions, *i.e.,* washing fruits a second time by showering them and working as a water dripping. The elevator takes then the fruits into the destoning machine (Figure 4A), where pips and around 90% of skin are separated from the pulp. Skin separation needs to be calibrated according to the desidered quality, since the proportion of skin into the processed mash

Figure 4. Equipment and process of the Alfa Laval system for cold-pressed avocado oil extraction. A) Avocado washer and de-stoning and peeling machine (*courtesy of Bertuzzi Food Processing*). B) Disc crusher for avocado fibre and skin chopping to minimise emulsion risks. C) Extra-virgin olive oil-Line flash thermal conditioning system. New development of Alfa Laval designed for thermal conditioning of the mash after crushing and before kneading. This system can reduce kneading time/volume and improve the avocado oil quality. D) Atmosphera malaxers/kneadings. Hermetic design for preserving the aromatic fraction of avocado oil. E) Decanter centrifuge for avocado oil and water separation from solids. F) Disk stack vertical centrifuge for avocado oil purification and potential oil recovery from water. G) Example of a complete centrifugation process solution from disk crusher to vertical centrifuge.

may affect the pigment composition of avocado oil (Ashton *et al.,* 2006; Wong *et al.,* 2011) like it does in olive oil (Criado *et al.,* 2007). Pigments are important for the intensity of the green colour, its stability and its healthy effects (Woolf *et al.,* 2009). The pulp (which is crushed during destoning) with a variable proportion of skin is pumped into a disc crusher (Figure 4B) for further refining. The disc crusher (Alfa Laval exclusive design) rotates continuously at 1400 rpm. The avocado mash is conveyed at the center and then sprayed towards the periphery by a toothed disc after the de-stoning process The disc crusher is important to cut the filaments remained in the paste and, at the same time, to minimise the emulsion. This approach has enabled us to optimise oil extraction. The same kind of disc crusher is used to crush the whole olive fruit and prepare the olive paste before EVOO extraction (Uceda *et al.*, 2006; Amirante *et al.,* 2010a). In addition the disc crusher has the important effect of chopping cutting very finely the skin for maximum pigment extraction. This disc crusher design is specifically used to extract olive oil with the maximum amount of chloropyll and carotenoid pigments (Costagli, 2006).

Thermal conditioning and kneading/malaxing

After crushing, the avocado mash is pumped into the section equipped with malaxers (kneading machines). Each kneading machine (Figure 4D) consists of a stainless steel tank with a central screw stirring the mash slowly and continously at a monitored temperature. The effect of the kneading machine on the avocado paste is very similar to the one already described for the olive paste: small oil drops released during fruit milling merge into large drops (coalescence phenomena) that can be easily separated by centrifugal extraction (Martinez Moreno *et al.,* 1957). The optimal malaxing time and temperature to reach the best compromise between quality and quantity of extracted olive oil has been investigate in depth. On average we should consider as optimal a malaxer temperature lower than 30°C and a malaxing time between 30 and 45 min (Angerosa *et al.,* 2001). Likewise, since the avocado oil comes in a finely dispersed emulsion inside the cells of the fruit pulp, the extraction process requires rupturing not only the cell walls, but also the structure of the emulsion (Lewis *et al.,* 1978). In the case of the avocado mash, our experience showed

Table 2. Example of process parameters measured during cold-pressed avocado oil production with different fruit batches (Hass variety) in New Zealand.

Batch number	Avocado fruit (kg net)	M time (min)	M Temp (°C)	Q (kg/h)	W (L/h)	Radius o/w (mm)	Δn (rpm)	Oil yield v/w (%)
1	1190	95	47-48	1200	500	107/110	9	12.6
2	1120	110	47-48	1200	500	107/110	9	13.1
3	620	85	47-48	1200	500	107/110	9	14.0
4	1230	95	47-48	1200	500	107/110	9	15.8
5	1230	100	47-48	1200	500	107/110	9	14.2
6	1370	120	47-48	1200	500	107/110	9	15.1

M, malaxer; Temp, temperature; Q, decanter throughput; W, water decanter dilution; o/w, oil/water radius liquid decanter outlet; Δn, differential speed.

Table 3. Proposed orgonoleptic and chemical parameters for cold-pressed avocado oil to be classified as extra virgin.

Parameter	Description/value
Odour and taste	The characteristic avocado flavour and sensory assessment shows at least moderate (above 40 on a 100-point scale) levels of grassy and mushroomy/buttery hints with some smoky notes
Defects	Minimal to no defects, such as palm-tree and fishy notes below 20 and glue-like notes below 35 on the basis of a sensory panel average on a 100-point scale
Colour	Nice and intense green
Stability	2 years at room temperature when stored under nitrogen and in the dark
Acid value	<1%
Peroxide value (meq/kg oil)	<4
Free fatty acid (% as oleic acid)	<0.5%
Smoke point	>250°C
Moisture	<0.1%
Palmitic acid (16:0)	10%-25%
Palmitoleic acid (16:1)	2%-8%
Stearic acid (18:0)	0.1%-0.4%
Oleic acid (18:1)	60%-80%
Linoleic acid (18:2)	7%-20%
Linolenic acid (18:3)	0.2%-1%
Vitamin E	70 mg/kg - 190 mg/kg

Modified from Woolf *et al.*, 2009, with permission.

that malaxing time should not exceed 90 min and temperature should be below 50°C. In particular the malaxing time is longer and the temperature is higher for avocados than olives due to the finely dispersed emulsion contained in the pulp cells. These emulsions are surrounded by the lipoproteic membranes or the lipophilic solids of the paste, which can absorb part of the oil itself. An oil-free paste and a good yield can be obtained by exploiting the mechanical and natural enzymatic action of malaxation (Dominguez *et al*., 1994). In olive oil it is amply demonstrated that a positive effect on the yield can derive from the use of physically draining products, such as talcum (Alba Mendoza *et al.,* 1982) or other enzymatic products (Di Giovacchino, 1991). This positive effect on the yield can certainly be obtained also in avocados without affecting the final oil quality. A laboratory test on avocado oil during mechanical extraction showed a positive effect of a treatment with α-amilase enzymes or a mixture of α-amilase and protease (Buenrostro and Lopez-Munguia, 1986). Coalescence and oil extraction are not the only purpose of the crushing and malaxing processesses. In EVOO extraction, the total phenol content and aromatic fraction are strongly affected by the extraction technology. In particular total phenols in EVOO drop when malaxing time and temperature increase (Di Giovacchino, 1991; Di Giovacchino *et al.,* 2002). Furthermore, aromatic compounds in EVOO are rapidly generated during olive crushing (Angerosa *et al.,* 1998). During this process, the evolution of the aromatic fraction is strongly influenced by malaxing time and temperature and shows different correlations depending on the different kinds of compounds (Morales *et al.,*1999; Salas and Sanchez, 1999; Angerosa *et al.,* 2001; Ranalli *et al.,* 2001). Also, although in CPAO the effects of the extraction technology on phenols and the aromatic compound content have not yet been investigated, we would expect to find a similar impact due to its similarity with EVOO. In this respect, we should therefore consider that the latest innovation introduced in the EVOO extraction technology by Alfa Laval could also be applied succesfully to CPAO.

In particular, a recent innovation, such as the hermetic sealed malaxer (Alfa Laval Atmosphera), makes it possible to ensure a perfect control of the head space gas in contact with the mash. This technology reduces the negative effects caused by a prolonged contact of the mash with oxygen and improves volatile compounds and the phenolic content in EVOO (Amirante *et al.,* 2003; Servili *et al.,* 2003a, 2003b). Moreover, very recently, Alfa Laval has introduced an heat exchanger for the olive paste which can make a flash thermal conditioning named EVOO-Line (Figure 4C). Thermal conditioning makes it possible to heat the mash after crushing and before kneading with the positive effect of increasing volatile compounds and reducing kneading time up to 50% (Esposto *et al.,* 2013; Selvaggini *et al.,* 2014). Because of the strong similarities between EVOO and CPAO, we believe that the positive effect of the Atmosphera malaxer and the EVOO-Line flash thermal technology reported in EVOO exctraction could also apply to CPAO and deserves being further explored.

Oil extraction

The separation of oil from solid and liquid phases is done using a decanter centrifuge (Figure 4E). This device exploits the centripetal acceleration to separate continuously a mixture of particulate solids and liquids with phases having different densities (Madsen, 1989). Alfa Laval found that the best decanter centrifuge applicable to CPAO extraction is the three outlet version. In this machine, the mash coming from kneading is fed into the machine together with about 10-20% of hot water (at the same temperature as the mash) depending on the characteristics of product. The mash inside the centrifuge is separated into oil, vegetation water and solids (exhausted pulp and residual skin). Exctraction is carried out in a continous system and can be continuously adjusted thanks to a particular Alfa Laval design with variable dynamic pressure (Amirante and Catalano, 2000; Catalano *et al.,* 2003). This innovation enables us to perform a real-time adjustment of the differential speed between drums and conveyors (Δn), and feed rate according to the characteristics of the raw material with high flexibility, a high level of oil clarification and reduced water consumption (Amirante *et al.,* 2010b). The oil phase and the water phase are collected separately under the decanter. The oil phase is pumped out to a vertical purifier centrifuge, while the water phase is pumped out to a vertical concentrator centrifuge.

Oil purification and recovery

The CPAO flowing from the decanter still has a certain amount of water and solids. Vegetation water from the decanter should still contain a small quantity of residual oil. Both liquid phases are sent to vertical centrifuges (Figure 4F), as already described for the EVOO extraction process (Uceda *et al.,* 2006). The system consists of a disk stack centrifuge for final CPAO purification to remove residual water and solids. A second disk stack centrifuge should be used to recover residual CPAO from the vegetation water flowing from the decanter. The latest improvement of the Alfa Laval decanter technology with three outlets reduces to almost 0% the residual oil in the water. Hence, the use of the centrifuge to recover a very limited quantity of CPAO from vegetation water should be evaluated according to economic constraints.

Process parameters, extraction rates and oil quality with the cold-pressed extraction method

As described above, the characteristics of avocado fruits can change depending on multiple variables. Variety, ripeness stage, geographical area, fruit humidity are some of main factors that affect extraction rates and the final quality of CPAO. The main quantity of oil is in the pulp of the avocado fruit (Lewis *et al.,* 1978; Jacobsberg, 1988). The avocado oil content in the pulp in terms of dry matter shows high genetical and ecological variability (Frega *et al.,* 1990; Shengzhong *et al.,* 1998; Gomez-Lopez, 1999; Bora *et al.,* 2001). From the experimental studies made in New Zealand, the extraction rates vary during the season, because the absolute oil content changes, and typically vary from 10 to 18% of whole fruit. Table 2 shows an example of different oil yields of CPAO extraction depending on different process parameters and show that in practice the yield depends significantly on fruit ripeness. It seems that the theoretical oil content in the fruit can be as high as 22% w/w, yet the current system can extract only 15-16% with a malaxing time not exceeding 90 min and a temperature below 50°C. Wong *et al.* (2010) reported that the avocado oil yield obtained in New Zealand with the cold pressing system can range from 15% to approximately 25%, depending on whether the fruits are in the early ripening stage or are fully ripen. In this respect, the extractability of CPAO should not differ significantly from that of EVOO (Beltran *et al.,* 2003). However further scientific investigation on this aspect, preferably on the industrial scale, is needed to have a better characterisation of the individual varieties, ripeness stages and process parameters of CPAO extraction plant.

CPAO is today commercialised all over the world. In order to ensure good CPAO quality, Woolf *et al.* (2009) propose the use of an *extra virgin* label based on a standard definition, quality indicators, composition and sensory properties. CPAO named also extra virgin avocado oil (EVAO) is defined as oil extracted from high-quality fruits (with minimal levels of rots and physiological disorders). Extraction should be carried out using only mechanical methods including presses, decanters and screw presses at low temperatures (<50°C). The addition of water processing aids (*e.g.,* enzymes and talcum powder) is acceptable, but no chemical solvents can be used. The chemical composition and organoleptic profile of extra virgin avocado oil are reported in Table 3 (Woolf *et al.,* 2009). The flavour of CPAO or EVAO is also described differently, as it varies depending on the cultivar. The Hass cultivar gives an avocado oil with grassy and buttery/mushroom-like flavours. Other varieties may produce oils with a slightly different flavour profiles, as it can be seen with the Fuerte cultivar that has a more mushroomy flavour and fewer typical avocado flavours (Wong *et al.,* 2010). The reported parameters refer to an edible high-quality oil that can be used for salad dressings and is comparable with EVOO. The cold-pressing extraction method described above compared with traditional methods can yield an oil with significantly higher pigment levels, a stronger flavour and, consequentely higher health benefits (Eyres *et al.,* 2001; Birbek, 2002). Moreover, the high content of monounsaturated fatty acids in the CPAO extracted from the Hass cultivar has a high smoke point (≥250°C), making it suitable for frying. Definitevely CPAO is a food comparable with high-quality EVOO, which is at the basis of the Mediterranean diet.

Conclusions

The cultivation of avocado fruits is continuosly growing as is the knowledge about its healthy effects and its consumption. The intuition of New Zealand companies in the late 1990's with the application of the cold pressing extraction method inspired by EVOO production has led to the introduction of a completely new food oil that is significantly important for its role in cooking and its health-related benefits. Over the last fifteen years, CPAO production has spread in many different countries and its market is set to grow futher also due to the increasing interest in high-quality and healthy fruits. Both CPAO and EVOO are extracted from the fruit pulp and share some basic principles of the production process. Since the characteristics of EVOO have been investigated in depth and correlated to agronomical and technological factors (Costagli, 2006), the same is recommended for CPAO which could offer an unexplored and wide range of potential flavours and characteristics. Moreover EVOO is an object of continuous research to keep improving its production technology, thus leading to a potential improvement in its overall quality (Clodoveo, 2013; Clodoveo *et al*., 2014). Furthermore, the same approach to technological development adopted for EVOO should be applied to CPAO so as to guarantee its continuous improvement and, consequentely, a growing market potential and spread around the world in the future.

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